Real Time Spectrum Measurement for Environmental Radiation Monitoring

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journal or publication title	CYRIC annual report
volume	1996
page range	217-221
year	1996
URL	http://hdl.handle.net/10097/50000

V. 5. Real Time Spectrum Measurement for Environmental Radiation Monitoring

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A multichannel analyzer (MCA) and real time spectrum monitoring method have been developed for the radiation monitoring system by Fuji Electric Co.Ltd. A MCA was designed to be installed at a local site of a radiation detector. A spectral data which has been measured and collected in the MCA in every 1 minute is sent to the operation console proceeding every measured data. Because of poor count rate, the raw data measured in 1 minute have large statistical error and do not form a clear energy spectrum. For obtaining clear spectrum, we compared the "running average (RA) method" and the "exponential smoothing (ES) method". The response of the ES method is initially faster than that of the RA method, but the total counts obtained by ES method is lower than the real counts. On real time monitoring, it is desirable that response time is as short as possible. We then adopted the ES method, and estimated a good functions suitable to obtain the fast response. We put four MCA monitors in our radiation control system and start operation.

Introduction

In order to monitor the radiation level due to various radio-nuclides and radiations contained in and around many radioisotope facilities and accelerator facilities, the gamma ray spectrometry is necessary. The detectors of the radiation monitoring system are generally set at local sites, separately from a radiation control room.

The monitoring system must be operated continuously and respond quickly to the change of radiation levels. The conventional MCA used in the laboratory is not designed to measure continuously for varying radiation with quick response and is also expensive.

For these reasons, spectrum measurement has not been applied to radiation monitors. Only the total count rates have been measured by using single channel analyzers.

We have developed a local setting MCA which is installed at monitoring station housing with radiation detectors and data reduction methods with a real time response to be used in radiation monitors.

Method of real time spectrum measurement

Table 1 shows the specification of the MCA. The MCA contains an amplifier, a high voltage power supply, a temperature sensor and optical interface for data transmission to the central console. Detector bias voltage, amplifier gain and measuring period are adjustable from the central console. The MCA is used together with a 5.08 cm diameter by 5.08 cm long NaI(Tl) detector.

A spectra measurement is repeated for 1 minute and, after each measurement, spectrum data are transmitted from the MCA to the operation console via an optical fiber cable. The personal computer in the operation console stores every 1 minute spectrum for long time interval.

We applied two computing method. Both methods have been utilized in digital count rate meters. One method is the "running average (RA) method".

Each spectral data transmitted from the preamplifier is stored in a rotating 10 stage memory stack. The most recent datum replaces the oldest one cyclically. Thus, the spectrum of the RA method shows simply the mean value of 10 minutes and its response is delayed depending on the radiation level.

The other method is the "exponential smoothing (ES) method", which responds exponentially to the change of radiation level.

$$N_i = R_i^{-1} \left[N_{in} + (R_i - 1) N_{i(n-1)} \right], \qquad (1)$$

$$\tau_i = (R_i - 0.5) \Delta t, \qquad (2)$$

$$P = \left[2 \tau_i N_{i(n-1)} \right]^{-1/2} \times 100, \qquad (3)$$

where

N_i = counts of i-channel after refreshment,

Ri = Exponential smoothing coefficient,

N_{in} = Counts of i-channel transmitted,

$N_{i(n-1)}$ = Counts of i-channel before refreshment,

τ_i = Time constant of i-channel, and

P = Relative standard deviation which is common to the whole channel.

The exponential smoothing coefficient R_i is derived from Eqs. (1), (2) and (3).

$$R_i = \left[2 N_{i(n-1)} \Delta t \right]^{-1} (100/P)^2 + 0.5 \qquad (4)$$

By setting the value of Δt(now, Δt = 1 minute) and P before hand, R_i is calculated with $N_{i(n-1)}$. Then, the count numbers of each channel are exponentially smoothed.

The time constant for each channel changes according to the count of each channel. As a result, relative standard deviations of the whole channel have the same value in the range of τ_i from 1 to 10 minutes.

Experiments of real spectrum

We put ^{137}Cs and ^{60}Co radiation sources which intensities were about 300kBq on the surface of the gaseous effluent detector and after about 15 minutes we removed the both sources.

Fig. 1 shows the change of the spectrum for every 1 minute analyzed by the RA method and Fig. 2 shows the change in the gross count rates of the photo peak area of ^{137}Cs 662keV gamma rays. The count rates lineally increase and decrease symmetrically.

Fig. 3 shows the change of the spectrum for every 1 minute analyzed by the ES method when the relative standard deviation is set to 5%. Fig. 4 shows the changes in the gross count rates of the ^{137}Cs gamma ray peak area when the standard deviation is set to 5%, 10% and 20%. With increase of standard deviation, the count rates rise up rapidly and rise down rapidly and the plateau peak range becomes wide, which indicates the quicker response. For obtaining real time response, it is therefore desirable to select large standard deviation, but data fluctuation become large.

Application to radiation monitors

We applied this real time spectrum measurement system in the radiation monitoring system at Cyclotron and Radioisotope Center of Tohoku university. Two area monitors were set at the boundary and two gaseous effluent monitors were set on two air stack of our facility.

We have a AVF cyclotron and the positron emitting nuclides of ^{18}F, ^{15}O and ^{11}C are produced routinely every week for radiopharmaceutical production for positron emission tomography study and also many kinds of radioisotopes which have brought in the facility are used.

Considering radioisotope releasing for short period from an air stack, we injected 1 ml of $^{11}CO_2$ gas of 500kBq to an input tube of the monitors. Fig. 5 shows the activity change. A solid line is the real activity change detected with the NaI(Tl) detector directly and a dotted and a broken lines are thoes analyzed with the ES and RA methods, respectively. The change of the ES method shows the similar shape of the real activity curve except for slower attenuation. But, the distribution of the RA method shows a quite different shape and a peak position of the RA method appears 10 minute later than real discharge time. By using the RA method, we can not decide the discharge time of radioisotope on time. Fig. 6 shows the spectra of area monitor set on the boundary of our facility. The peak of 1.46MeV is the gamma rays of ^{40}K and the peak of near 0.55MeV is the mixed gamma rays of ^{208}Tl and ^{214}Bi. These are all natural isotopes and artificial isotope is not recognized.

Summary

We have developed an MCA and two real time spectrum monitoring methods for use in the radiation monitors. The "running average method" cannot keep up with radiation changes. The "exponential smoothing method" has a fast response because of an automatically variable time constant. The latter method is preferable for area monitors and gaseous effluent monitors.

Table 1. Specifications of the MCA.

Bias voltage supply	600 - 1,200 V
Amplifier gain	1.1 V/pc ×1,2,3
ADC conversion gain	512 ch
Counts per channel	$2^{16}-1$
Integral non-linearity	± 0.5 %
Differential non-linearity	± 2 %
Operating condition	0-45 ℃, 95 %RH

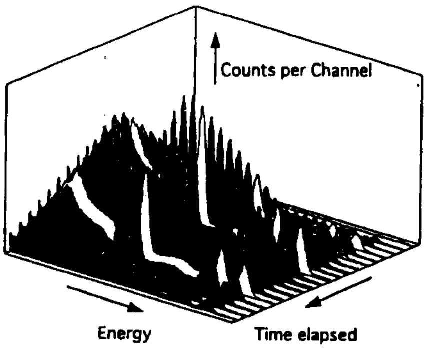

Fig.1 Changes in spectra analyzed with running averaging method.

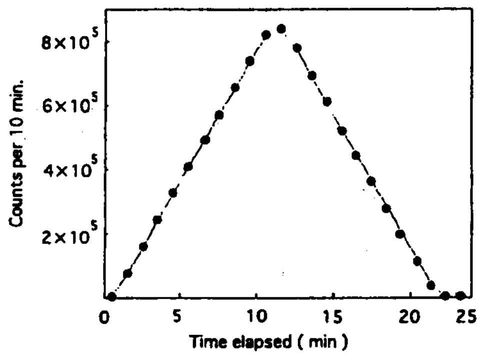

Fig.2 Changes in gross counts of ^{137}Cs with running averaging method.

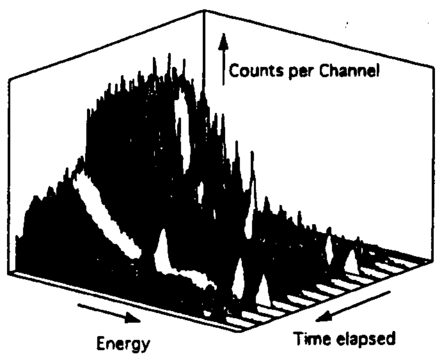

Fig.3 Changes in spectra analyzed with exponential smoothing method.

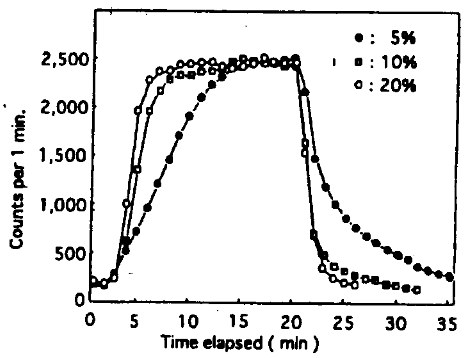

Fig.4 Changes in gross counts of ^{137}Cs with exponential smoothing method.

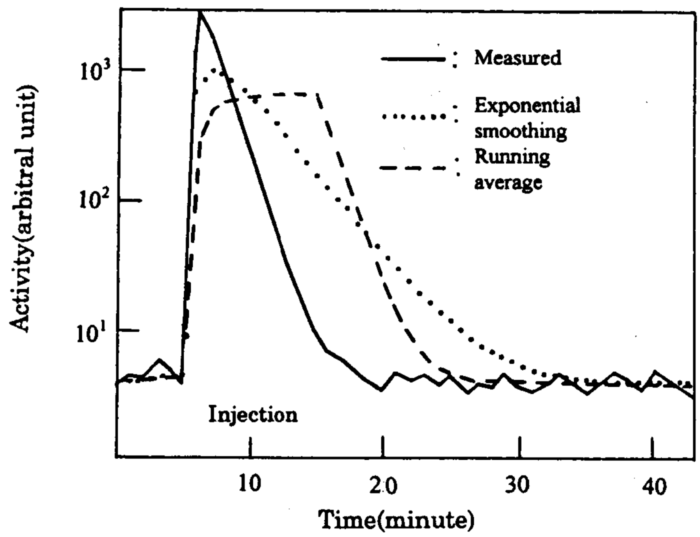

Fig. 5 Comparison of running averaging method and exponential smoothing method with use of active gas $^{11}CO_2$

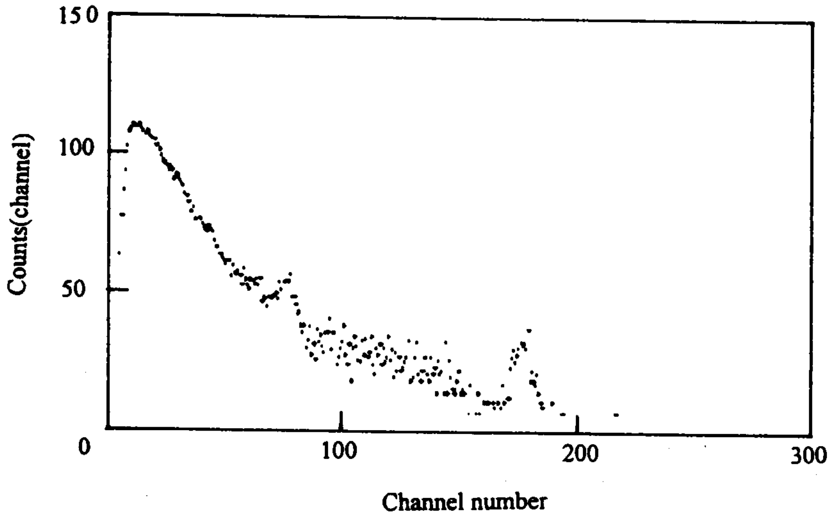

Fig.6 Spectra measured at monitoring post and analyzed with exponential smoothing method.